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## Development of a dual control system applied to a smart wheelchair, using magnetic and speech control.

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### Abstract

The use of Power Electric wheelchairs for physically disabled people is becoming increasingly common; however the systems used in order to manage it are reduced to the use of specialized drivers, only using joysticks to manipulate the wheelchair, and these are generally suitable only for patients with motor disabilities in their lower limbs. This paper proposes the development of a speech control system and a magnetic control system to drive a wheelchair as an alternative for patients with severe disabilities. Both are applied to a smart wheelchair; the proposed systems include the development of new communication protocols for the wheelchair through a microcontroller, an H-bridge, a microphone and a magnetic control.

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## 1. Introduction

The ability to moving independently is essential for the full development of our lives [1], for that reason it is necessary to carry out work aimed at helping people with a motor disability as quadriplegic or tetraplegic to have adequate tools for mobility, so they can reintegrate into society and improve their productive life [2].

According to the Population and Housing Census 2010 of the National Institute of Statistics and Geography (INEGI) [3], in Mexico there are 5,739,270 people with some kind of disability. Additionally the motor impairment is the most frequent among the country's population (58.3%). These statistics show the large number of people with mobility disabilities in Mexico (29 out of 1000). Moreover the decrease in mobility is often a reduction of opportunities for socializing, which leads to a patient suffering social isolation, anxiety and depression, leading to less health welfare [4].

For patients who have mobility in their upper limbs, the use of mechanical or electric wheelchairs represents a way to regain some of their mobility, however it is important that the user acquire the knowledge and skills to handle them, for that it is necessary a training program for its correct use and thus help users with the personal acceptance of their disability to improve their quality of life [5]. For patients who cannot use their upper and lower limbs, but they are able to use skills other than above, such as the movement of the eye [6], face [7], hand [8], tongue [9] or the sound of the voice, have been proposed different wheelchairs that exploit these control systems [10]. However, these technologies are still emerging, especially in our country. For this reason, in recent years, one of the most necessary tasks is to provide tools that help not only patients with motor disabilities, but also people with other disabilities, such as mute, deaf, blind or quadriplegic.

The need to create new interfaces that allow a more natural interaction with a wheelchair has motivated this paper. The proposed systems integrate a magnetic control interface using a magnet and a voice control interface using a microphone with the elements of a prototype wheelchair that it can perform a simple command control, for that were implemented, a magnetic control system and a speech recognition system.

## 2. Magnetic Control System

While many devices are available to help people with lower levels of disability, people with a capacity of minimal or no movements (for example, people with quadriplegia) probably need more assistance and they have very limited options for take care of themselves. Assistive technologies help improve the quality of life for people with severe disabilities and considering these trends, are essential to help them; therefore it is necessary to use very specific skills that patients can do without problems, as the movement of tongue [11].

The tongue is connected to the brain by the hypoglossal nerve, which generally escapes severe damage in spinal cord injuries and is similar to heart muscle that it does not fatigue easily. Moreover, the tongue is semi-invasively accessible and not influenced by the position of the body, which can be adjusted for maximum comfort. The mouth and tongue occupy an amount of motor and sensory cortex in the human brain that rivals that of the hand and fingers. Therefore, they are inherently capable of sophisticated motor control and handling tasks with many degrees of freedom. The movement of the tongue in the mouth is intuitive and fast. It is known that the tongue training with a simple protrusion task induces neural plasticity [12]. Consequently, the tongue appears to be appropriate as a new control interface. The researchers, who have tried to use the tongue as control device, mostly used a system of direct contact, for example, the implementation of the tongue with metal piercings or magnetic accessories [13]. The sensors are placed on the tongue inside the mouth and these are then detected by either a dental retainer used in the mouth or by a separate device worn outside the mouth. The magnetic control system that was proposed in this paper is operated by tongue and its use is for severely disabled people as tetraplegia patients in order to improve their mobility and is divided into 4 phases, Figure 1 shows all the phases of the magnetic control system.

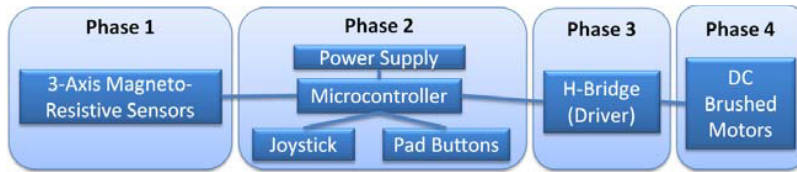


Fig. 1. Block diagram: Phases of the magnetic control system

However, unlike other magnetic control systems for the tongue, the position of the magnet in the mouth is different from other systems. Usually a pair of magnetic sensors is mounted symmetrically at a right angle on a pair of goosenecks from a headset, and then the sensors are placed close to the user's cheeks to detect variations in the magnetic field of the magnet that is on the tongue. But for the current system of assistance for the wheelchair, the goal was to handle an electric wheelchair with simple commands to get move in a room with precision using an interface easy-to-use, minimally invasive, low-cost, reliable and unobtrusive. So the magnet is not placed on the tongue, but is in the dental retainer with a small rail behind the teeth, where the magnet can be moved in 5 positions by the tongue, as can be seen in Fig. 2 (a).

### 2.1. Phase 1

This phase basically uses a pair of 3-axis magneto-resistive sensors, these are surface-mount, multi-chip module designed for low-field magnetic sensing with a digital interface for applications such as low-cost compassing and magnetometry. These anisotropic, directional sensors feature precision in-axis sensitivity and linearity. These sensors' solid-state construction with very low cross-axis sensitivity is designed to measure both the direction and the magnitude of Earth's magnetic fields, from milli-gauss to 8 gauss.

The magneto-resistive sensor modules are placed in a headset, as seen in Figure 2 (b), and after receiving the command signals, they are sent to the microcontroller system.

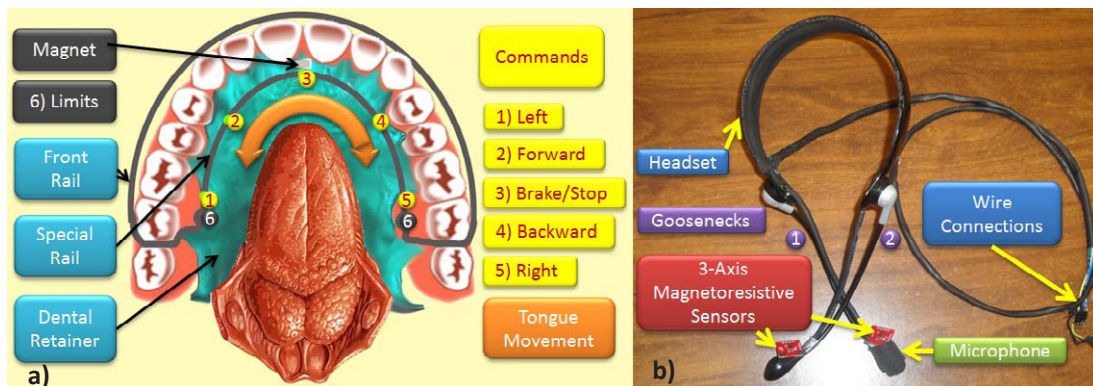


Fig. 2. Devices for magnetic control system: a) dental retainer with a magnet; b) headset for magnetic and speech control system

### 2.2. Phase 2

For phase 2, wheelchair's batteries have to supply +24VDC to the motors, so it was decided to supply the systems with +5 VDC with help from a high power voltage regulator, besides the tongue commands were programmed to sense changes in the magnetic field of the magnet embedded in the dental retainer, according to the movements of the tongue, as shown in Figure 4a. When commands are configured, it is important to correctly position the sensors close to the cheeks of the patient, at the right angle to get precision in the

movements of the wheelchair. The programming of the commands is performed on the arduino environment, using a microcontroller, ATMEGA2560, which is located in the circuit board Arduino Mega ADK for processing the signals of the magnetic control system with an I2C interface. To explain how it works microcontroller's programming, Figure 3 shows more in detail the processes performed by the system. On the other hand, pad buttons and joystick's circuits were added alternatively to control the movement of the wheelchair to connect analog and digital inputs to determine the directions that follow.

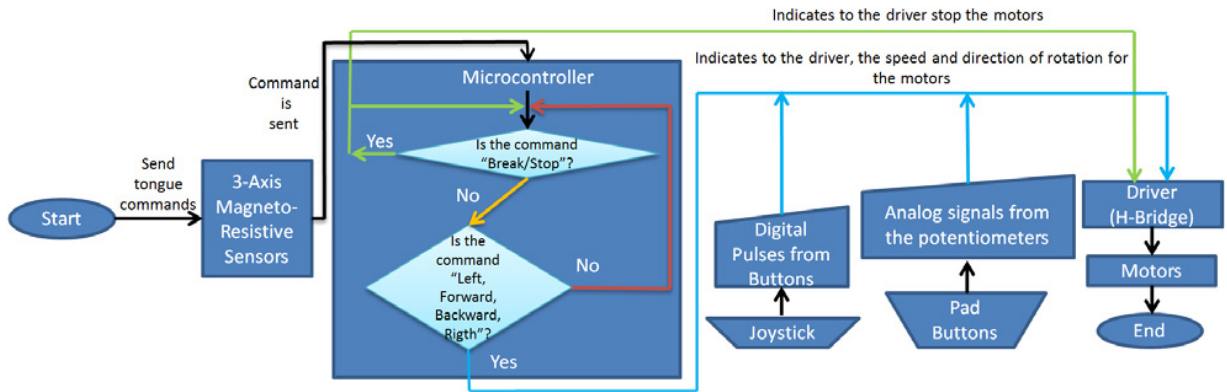


Fig. 3. Flow diagram: Magnetic control system

### 2.3. Phase 3 and 4

The 3rd and 4th phase focuses on using a driver (H-bridge) that receives signals from the microcontroller and this in turn provide the necessary voltage to the motors through a PWM control technique. The driver used was a dual motor driver sabertooth 2x60; is one of the most versatile, efficient and easy to use on the market. Among its most important specifications are able to work with a 6V-33.6V input voltage, output current: 60A per channel, 120A peak output current per channel, and 3 operating modes: analog, R / C and serial. As can be seen in Figure 4 are shown more details about the input and output pins.

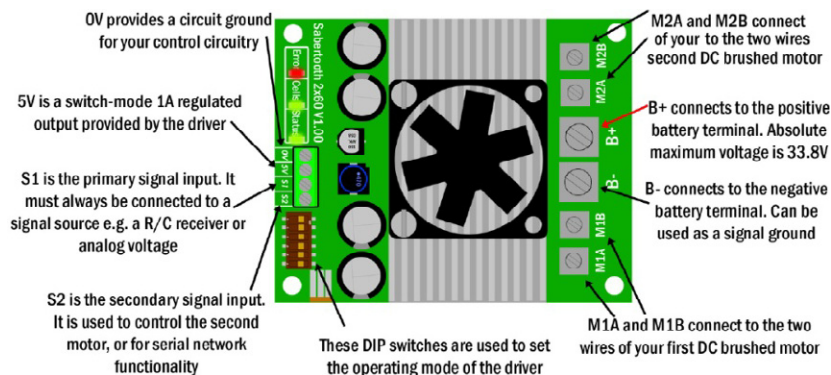


Fig. 4. Sabertooth 2x60 motor driver pinout guide

## 3. Speech Control System

This system is designed to benefit users who have lost control of their upper extremities as well as the lower. In particular, the speech recognition system consists of two parts: the first part is a section with a small

vocabulary training that builds a model, and the second is a speech recognition section which uses this model. The whole system is divided into five stages, as can be seen in Figure 5; the phases of the speech control system proposed are shown.

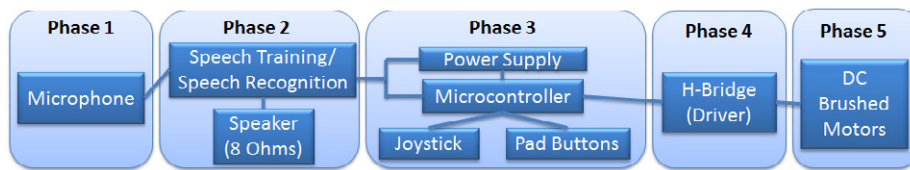


Fig. 5. Block diagram: Phases of the speech control system

### 3.1. Phase 1

This phase is responsible for receiving the user's voice commands through a microphone electret condenser omnidirectional; microphone circuit was mounted on a headset as shown in Figure 2 (b) with a flexible tube that allows placing the microphone in different positions, besides that the base of the flexible tube rotates to move and position the microphone easily to any height close to the user's mouth.

### 3.2. Phase 2

In this phase, before performing another activity were defined primarily the voice commands that were used to control the system voice which can be seen in the following Table 1.

Table 1. Commands for the speech control system

Commands	Action
One	Power on the system
Forward	Move forward
Backward	Move back
Left	Turn to the left
Right	Turn to the right
Down	Brake motors
Up	Shut Down (Stops also engines)

Then the voice commands were programmed and trained to respond according to the recognition system, to be applied to a wheelchair using the speech recognition board "EasyVR" that uses classic speech recognition algorithms [14]. Thus when the microphone receives the voice commands, the board recognizes commands one by one and when that command is identified, the board sends a signal to the microcontroller that is in the next phase of speech control system. In Figure 6, the command "one" activates a boolean state for continue with the next commands and the command "up" turn off the system. Note that the circuit board is a multi-purpose speech recognition module designed to easily add speech recognition capabilities making it very versatile, robust and effective for virtually any application. The EasyVR module can be used with any host with a UART interface powered at 3.3 V 5V, such as PIC and Arduino boards. In this module, you can use independent commands (default memory card) or dependent commands (user defined to train the card). And finally an additional feature that was used in the same, was to download a table of sounds (in .WAV,



22050 Hz, Mono, 16-bit uncompressed) with which it recognizes a voice command, then sends a signal that activates a sound of the table through an 8 ohm speaker to respond to the command, managing to make the system more interactive.

### 3.3. Phase 3

Within this phase, the programming for the voice control system (Figure 6) is different from the magnetic control system, since the inputs and outputs for the Arduino platform were taken advantage to use their digital and analog ports to receive or send information to their different phases [15], with particular emphasis on programming the response time to receive voice commands and perform the action that was assigned to each command [16].

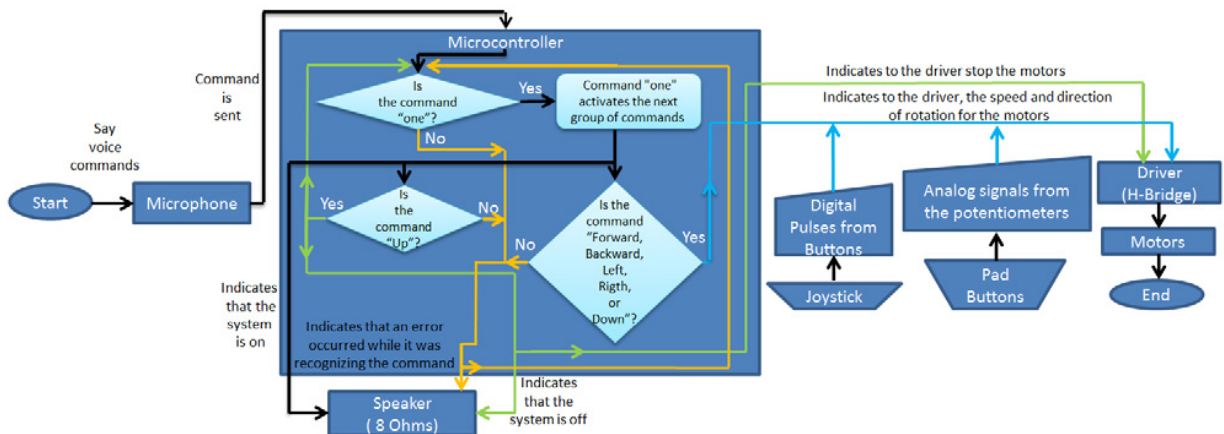


Fig. 6. Flow diagram: Speech control system

### 3.4. Phase 4 and 5

For this phase, after which the signals were received and processed both by the voice module and the microcontroller, the latter in turn generates new signals that carry the information for the speed and direction of rotation of the motors (Figure 7), i.e., is responsible for generating the two PWM signals and the correct switching for changing the direction and rotation of motors.



Fig. 7. Diagram of electric wheelchair implementing systems: a) top view; b) bottom view, c) photography

## 4. Results

The results have allowed us to show the feasibility of making a wheelchair with a voice and magnetic control at low cost.

### 4.1. Speech recognition control

The use of this control showed that it is able to recognize the commands programmed and then the system performs scheduled tasks for each command, also activate the sounds that were saved in the memory of speech recognition module to verify that the command was correct. Table 2 shows the results by repeating 100 times each command, on the other hand the runtime was taken using an oscilloscope to know how long it takes the system to recognize it, and finally the percentages of assertiveness are also shown with respect the number of times the system correctly recognized each command.

Table 2. Percentage of assertiveness for each command of speech recognition

Commands	Runtime	Percentage of assertiveness in speech recognition
One	10 ms	100 %
Forward	21 ms	95%
Backward	20 ms	100%
Left	12 ms	90%
Right	16 ms	92%
Down	13 ms	97%
Up	11 ms	96%

### 4.2. Magnetic Control by the tongue

For this system, the dental retainer with the embedded magnet was placed first in the user's mouth. Then, the headset was used with care, besides the magnetic sensors and microphone were placed near the user's cheeks and mouth. Finally when the system was turned on, the user wheelchair drove through a road, which was designed so that the user will use the five commands that the system allows, as can be seen in Figure 8. This experiment was performed with five different people and all successfully completed the course with an average time of 167 seconds using speech recognition and 182 seconds with the magnetic system.

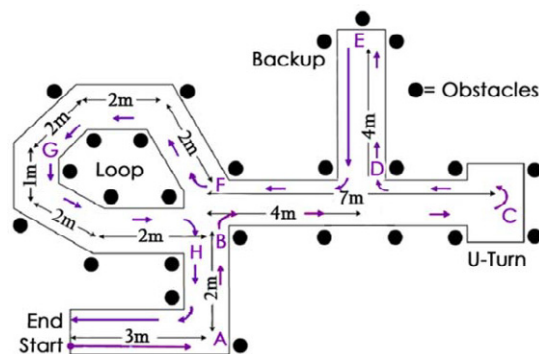


Fig. 8. Obstacle course to test the performance of the electric wheelchair

## 5. Discussion

It was possible to develop a speech control that had a successful recognition rate of 95.71%, which works with any type of voice; this percentage is pretty good because the speech recognition systems usually fail to be too assertive [17]. However, if it is required to customize a single voice is also possible to train the module to recognize only certain tones of voice. The memory limit that owns the microcontroller and the speech recognition module, restrict and limit training commands and for this reason are planned for future works, use an external memory or a computer with enough capacity to reduce the time response between the recognition of the commands and execution of assigned tasks. Finally, the magnetic control system, proposes using the magnet in the dental retainer because other systems place the magnet on the tongue with tisular adhesive which only lasts a few hours [18], or even newer systems use magnetic piercings in patients with severe disabilities [19] making them suffer unnecessary pain, besides the use of piercings gradually generates chipping of the dental enamel, periodontal lesions and infection tongue numbness [20]. In the other hand with the current wheelchair, the users who used it in the experiment and although some took longer to complete the course than others, with proper training anyone who can use the tongue will be able to drive it.

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